SEAFRAME

2008 • VOLUME 4 • ISSUE 2 Carderock Division Publication

Greening Up by Reducing Shipboard Waste

Advancing Desalination for Emergent Navy Needs Worldwide

Oil Industry Technology Helps to Reduce Shock Trial Costs

Teaming Internationally on Affordable, Lightweight Composite Hulls

Leading the Way to a Global, Integrated Approach to Naval Architecture and Marine Engineering

NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE **SeaFrame. Volume 4, Issue 2, 2008**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center, Carderock Division,Code 3443,9500 MacArthur Blvd,West Bethesda,MD,20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**24**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Carderock Division Publication

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Striving Toward International Leadership in Naval Architecture/Marine Engineering

By Captain Mark W. Thomas, C. Randy Reeves, and Captain Mary J. Logsdon

For many years a strategic plan has been used to guide the activities of the Carderock Division. In our 2007 planning cycle, we were particularly fortunate because it dovetailed with the unveiling of the new CNO Maritime Strategy.

The Cooperative Strategy for 21st Century Seapower moves us from a cold war naval strategy to a more global and integrated approach toward forward presence, expeditionary warfare, peace-time operations, and crisis response missions. Although it is unique in many ways, the 2007 Maritime Strategy reaffirms the Navy's obligation to remain the world's preeminent maritime nation. The strategy, however, also recognizes the need to develop international partnerships and foster more cooperation among all the sea services.

As you will see from the articles in this issue of SEAFRAME, the Carderock Division has advanced its technical capabilities to support this strategy.

To that end, Naval Surface Warfare Center, Carderock Division developed and received approval for a new mission statement: *To provide research, development, test and evaluation, analysis, acquisition support, in-service engineering, logistics and integration of surface and undersea vehicles and associated systems. To develop and apply science and technology associated with naval architecture and marine engineering, and provide support to the maritime industry.*

As the result of an off-site strategic planning session, Carderock Division leaders developed our vision statement to reinforce our mission and to guide us into the future. It states that we want *"to be the worldwide technical leader for naval architecture and marine engineering."*

For more than a century, the Carderock Division has developed the technical capabilities to support Navy and military requirements. Because the mission of the Division is oriented to platform systems, however, many of these capabilities are applicable to all of our sea services and naval allies. In fact, the Division is uniquely chartered by Congress to support America's maritime industry.

The key to our long-term success is our knowledge of the full spectrum of applied maritime science and technology, ranging from the theoretical and conceptual beginnings through design and acquisition to implementation and follow-on engineering. Our recent strategic plan reaffirms our vow to retain our scientific and technical leadership in naval architecture and marine engineering which, in turn, will support the maritime community. Our current issue of SEAFRAME illustrates the many ways we are working with other nations and navies to support the sea services. To set the framework for the accompanying articles, please refer to *The Cooperative Strategy for 21st Century Seapower,* at www.navy.mil/maritime and the introduction to the Carderock Division Strategic Plan on page 2.

SEAFRAME, of course, can only describe a small fraction of our work. We have numerous, ongoing independent efforts and partnerships with industry, academia, and our international partners to develop innovative technology for the future. Our strategic plan is also in place to serve as a living document to ensure that we do our part in helping the U.S. Navy retain its place as the preeminent maritime power.

SEAFRAME
Carderock Division Publication
2008 • Volume 4 • Issue 2

SEAFRAME is the official publication of the Naval Surface Warfare Center, Carderock Division. It is published quarterly with appropriated funds in accordance with NAVSO-P35. Any views and opinions expressed are not necessarily those of the Department of the Navy.

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On the cover: A Multinational Force– This issue of SEAFRAME illustrates many ways Carderock Division is working with other services, nations, and navies to support *The Cooperative Strategy for 21st Century Seapower.*
U.S. Navy photo.

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Looking Toward the Future

Business

Carderock Division Develops a Strategic Plan Focused on Being the Worldwide Leader in Naval Architecture and Marine Engineering

By Arnold Ostroff

The future is the great unknown. Nevertheless, people, organizations, and societies dedicate a lot of time and attention to trying to capture a picture of what the future holds. We in the Carderock Division are no exception. We examine potential future conditions, project our role under those conditions, and with an understanding of our current and needed future capabilities develop goals and strategies to meet that future state. This process of assessment and objective-setting is the basis of strategic planning. The plan will help us make better decisions and allocate our resources in accordance with our values and desired future.

A strategic plan is only useful if it is reviewed and updated periodically. The last Carderock Division strategic plan was developed more than five years ago. Since then, many changes have occurred, both within and outside of the Division. To address the impacts of these changes, the Carderock Division began work on a new strategic plan that would strengthen our capabilities and allow us to better meet the needs of the future Navy.

The strategy update process began in December 2007 in Hunt Valley, Md., where senior Division leaders met for a two-day workshop. During the session, they drafted a new vision statement, guiding principles, strategic goals, objectives, and strategies. They reviewed information from higher-level commands such as the Warfare Centers, NAVSEA, and the Chief of Naval Operations as guidance. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) assessment was also developed to identify critical issues that could impact the plan. Over the next several months, the workshop results were refined, and a method for implementation developed. The final draft has been completed, and printed copies will be available later this summer.

Here are some of the principal features of the plan:

<u>VISION:</u> A vision statement promotes change by providing a glimpse of what the future could become. It is a statement of desired future state and answers the question “What will success look like?”

Our vision is to be the worldwide technical leader for naval architecture and marine engineering.

<u>GUIDING PRINCIPLES:</u> Guiding principles are beliefs and values fundamental to an organization. They are transformed into behaviors that underlie decisions and performance. Our nine guiding principles focus on how we value:

1) the Warfighter and the fleet,

2) our customers and stakeholders,

3) our people,

4) our technical excellence,

5) our stewardship and capabilities,

6) our productivity,

7) our integrity,

8) our innovation, and

9) our communication,

as well as what we as an organization need to do to demonstrate that value and meet the challenges in those areas.

<u>STRATEGIC GOALS AND OBJECTIVES:</u>
We have developed four strategic goals that identify essential areas of future need:

<u>Workforce:</u> Recruit, develop, and retain a diverse world-class workforce capable of sustaining the U.S. Navy’s superiority through application of the Carderock Division’s technical capabilities.

Facilities: ***Provide the Navy with highly capable and technologically advanced facilities, equipment, and information technology assets necessary for the Division's support of current and future ships and ship systems needs.***

Processes and Tools: ***Advance the Division's processes and tools to enhance effectiveness, affordability, and value to the customer now and in the future.***

Customers and Stakeholders: ***Serve as the trusted partner with our customers and stakeholders to strengthen the Navy Enterprise and our service to the fleet.***

The plan, itself, describes objectives that will help us meet each of these goals. After the strategic plan is issued, we will begin to implement the goals and objectives. This will be done by Leadership Focus Teams chaired by department heads. Each team will identify various strategies, measures of success, and resource needs for attaining the objectives. The strategic plan will be part of our ongoing process of future direction-setting, environmental awareness, self-evaluation, and continuous improvement. We will also use it to maintain focus, communicate values, and provide a clear sense of direction to those inside and external to the Division.

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BUSINESS

Patents: A Key Metric

Carderock Division Excels in Intellectual Property

By William Palmer and Leslie Spaulding

With a vision to be recognized worldwide as the technical leader for naval architecture and marine engineering, it's crucial that Carderock Division be in the forefront of intellectual property. According to Naval Surface Warfare Center Technical Director Stephen Mitchell, Carderock Division's metrics say it all.

Noting that the Navy has had more patents granted than the U.S. Army, NASA, the U.S. Air Force, and the Department of Energy, not to mention lead university systems such as MIT, CalTech, Stanford, and Johns Hopkins, Mitchell stated, "The bottom line is that we exist to serve the Navy and enable the warfighter. [Carderock Division's] achievements have indeed been remarkable, in terms of the intellectual property that was generated. ...If you look at Carderock Division's performance in the period of 2002 to 2005, you have the largest number of patents (156) for a Surface Warfare Center." In Fiscal Years 2006 and 2007, alone, Carderock Division was granted 66 patents and applied for 44 additional patents.

Added Captain Mark W. Thomas, Commander, NSWC Carderock Division, "The organization that is now Carderock Division has over 100 years of experience in discovering and creating new ideas for the benefit of the fleet. It brings unique facilities, unsurpassed knowledge of ships and ship systems, and a dedication to combining requirements and technology to meet Navy needs."

Since the inception of the *Vice Admiral Harold G. Bowen Award*, the Navy's most prestigious recognition for patents, Carderock Division employees were awarded 6 of the 14 total awards. To be recognized with this award, patents must meet stringent criteria and demonstrate significant benefit to the Navy.

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Ship Integration & Design

Computational Tools for Combatant Craft

Meeting Future Warfighters' Needs in the Littoral

By Jennifer Grimsley and E. Gordon Hatchell

The Naval Surface Warfare Center, Carderock Division (NSWCCD), Combatant Craft Division (CCD), is undertaking an RDT&E program to verify and validate physics-based computational tools for the design, selection, and optimization of high performance combatant craft. These tools are required to support a wide range of technical and acquisition goals, from concept design and evaluation to detailed design optimization.

These tools will also lead to a better understanding of the interaction of sea state, hull form, craft speed, resistance, powering, hydrodynamic loading, and structural response. Trained professionals in the DoD workforce will provide resource sponsors with smart-buyer solutions during the source selection process. This should result in fielded assets capable of high speeds in high sea states, increased payload capability without compromising structural robustness, and enhanced crew performance in the harsh environments created by high-speed transits.

The role of high-speed combatant craft and other littoral vessels in military operations is expanding due in part to the ongoing Global War on Terrorism. High-speed craft are operating in coastal waters and the open ocean supporting missions set by CCD's sponsors, which include Naval Special Operations, Naval Expeditionary Warfare, United States Marine Corps, and Homeland Defense. Expanding mission requirements can not be met using current combatant craft design techniques. Newer boats operate at higher speeds and have a wider range of hull shapes because new construction methods and materials enable designers to vary hull bottom shaping. For novel hull forms, very little validated performance data exists, and prediction methods are inadequate. Current, empirically based design procedures are outdated, limited in scope, and do not reflect the state-of-the-art in terms of high-speed craft.

To generate these tools, this development program applies computational fluid dynamics (CFD), fluid-structure interaction, multi-disciplinary optimization using finite element analysis (FEA), computer-aided design, and advances in material and craft construction. Goals are to develop, verify, and validate a robust set of design and evaluation tools that will be used to produce high-speed combatant craft capable of operating in all ocean environments. The initial effort evaluated existing, commercially available computer codes' ability to accurately predict craft performance. This led to developing and executing a multi-year program focused on Reynolds Averaged Navier Stokes Equations (RANSE) code validation for the hydrodynamic performance of advanced hull forms. As a result, CCD is developing and

Right and below: Data gathered during tests conducted on high performance craft, such as the *Sealion II* smaller craft and the MK V Special Operations Craft, are critical to verification and validation of computational tools being developed by Carderock Division engineers and scientists.
This page photos provided by Robert Gradel, NSWC Carderock Division Contractor.

Above: Wave damage to this MK V Special Operations Craft highlights the pressing need for a better understanding of both effective craft design and material capabilities and limitations. Development of robust computational tools will lead to improved design processes which are both more efficient and less expensive than current techniques.

validating computational tools for the design of advanced combatant craft. These tools must be computationally robust and able to accurately predict hydrodynamic loading, craft motions, and structural response.

Once validated, these design tools will be used for acquisition support–including source selection evaluation–and as an approved alternative to model testing. This should result in a cost reduction to program and acquisition sponsors of future designs. From a designer's standpoint, this program will lead to a better understanding of the interaction of sea state, hull form, hydrodynamic loading, and powering. This enhanced capability will enable craft designers to create high performance craft designs, while adding increased payload capability and improved operator performance in harsh environments.

CCD's jointly sponsored program is funded by U.S. Special Operations Command, the Office of Naval Research, Defense Director of Research and Engineering, and the NSWCCD Board of Directors. Personnel from multiple codes within NSWCCD execute projects ranging from model and/or full-scale testing of a variety of hullforms to CFD and FEA using commercial software. The verification and validation process is ongoing through FY 10. Beginning in FY 09, the tools will also be used for future craft design and optimization and to aid in source selection during the acquisition process for new procurement programs, to maximize the integration of technology in both form and function, and to ensure future vessels meet the increasing needs of the U.S. warfighters.

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Hull Forms & Propulsors

Seatrain

Unique Connectorless Units Provide New Sealift Solution

By Gabor Karafiath and William Palmer

Significant interest has developed in creating a military supply line to an austere access port (AAP). A vehicle designed to move into the AAP would be limited in length and draft. The ship to fit this mission would travel at a desired 35 to 40 knots, and the hydrodynamics of the design would dictate that the ship be very long–so long, in fact, that the ship could not enter the AAP. Also, this very large sealift ship, although capable of delivering a massive amount of cargo at unprecedented high speeds, would be too expensive to operate daily to serve in a peacetime oceanic transportation mode. The AAP requirement leads us to smaller, shorter ships which poses the difficult problem of independently operating at high speeds efficiently. The individual units however would be more viable in daily peacetime operations that may not require high speed and massive cargo capacity.

Ongoing testing and evaluation at Naval Surface Warfare Center, Carderock Division's (NSWCCD) David Taylor Model Basin is investigating a concept called a seatrain. A seatrain uses a connected series of units which are collectively capable of delivering the required cargo. Each unit has a much shorter length and has individual powering capability so that each could proceed into the AAP under its own power. The concept is not new, as models have been previously tested in which amphibious designs were joined together to increase the transit speed between ship and shore where conventional port facilities are unavailable. These amphibious vehicle designs operated at low speeds of 8 to 12 knots due to their poor hydrodynamic shape. Additionally, past efforts were undertaken to improve the speed and stability of ship-to-shore transfer utilizing large, barge-like platforms linked together to form floating piers/causeways. These structures are termed Navy lighterage. Testing of Navy lighterage systems and mobile offshore bases has helped researchers understand the nature of connector loads between units. The interface ideology of the current seatrain stems from the knowledge of Navy lighterage and mobile-offshore-base-connector loads.

Initial testing showed that it is possible to maintain hydrodynamic compressive forces between the units of the seatrain without the need for a physical mechanical connection in tension at the interface. The units of this concept, developed at NSWCCD, have a conventionally-shaped bow and a basic V-shaped notched stern. The bow of a trailing unit fits into the V-shaped notched stern of the unit ahead. Model Basin testing was conducted with one, two, three, and four units. Each unit is identical and waterjet-propelled. Experiments have been conducted both in calm water and in head seas, with each unit having the freedom to heave and pitch. The tow force imparted on each unit was measured allowing the interface forces to be determined using propulsion estimates from standard practices.

The experiments showed that seatrain combinations give between 40 percent and 50 percent reduction in resistance in comparison to the units operating independently. A 10-knot increase in speed for the same installed power is achievable with the seatrain configuration. The speed increase is due to the great increase in waterline length associated with the combined units. Also, experiments in head seas up to a sea state 6 show that a 3-unit seatrain

Seatrain units under tow at NSWCCD's David Taylor Model Basin. Combined hydrodynamic efficiency increases when units operate closely in tandem formation.
Photo by Jesse Geisbert, NSWC Carderock Division.

maintains the powering performance advantage in a sea state. In higher sea states, the units are envisioned to simply disengage and proceed individually under their own power until the sea state ameliorates, and they can re-engage.

Another important design aspect verified in testing was that outboard deflection of the leading unit waterjet wash results in an amelioration of the drag on the trailing unit. Orienting the waterjet nozzle outboard to match the half entrance angle of the trailing unit appears to solve the adverse drag impact that the wash would normally have.

Seatrain units hold the promise of enabling the Navy to meet Seabasing mission requirements through their unique design and innovative connectorless concept.

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MACHINERY SYSTEMS

ADVANCED DESALINATION FOR SHIPBOARD APPLICATION

Modernizing the Navy to Meet the Changing Needs of the Fleet

By David J. Nordham and Joseph F. Pizzino

Naval operational strategies are changing with the times, and with these changing strategies, hull and deck machinery and operational modes will necessarily need to change. New operational strategies identified by the Chief of Naval Operations in *A Cooperative Strategy for 21st Century Seapower* will require seamless naval operations in littoral and coastal zones to "...overcome challenges to access and to project and sustain power ashore. ..."

This has essentially been borne out in recent naval operations in the 5th Fleet Area of Responsibility (AOR)–with ships operating in support of and in close proximity to troops operating in Iraq and Afghanistan. Navy ships operating in this AOR region have experienced severe increases in maintenance requirements for their reverse osmosis (RO) desalination plants. Operations in coastal regions have significantly reduced the operational life of the RO cartridge filters. Filters are lasting much less

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than the 1,000 hours of open ocean design life, significantly increasing ship's force maintenance manhours and costs. In addition, RO membranes, the heart of the system–used for actual salt separation–are experiencing premature failure.

RO desalination plants have been replacing distillers in the Navy since the 1990s. These systems have been installed on most new ships and backfit on many older ships and submarines. Unlike distillers, RO systems operate without continuous monitoring, require significantly less maintenance, require less energy, and exhibit a high reliability. Total Operational Cost of RO is very low. However, operating in coastal zones where seawater contains high levels of organic solids can challenge RO plants.

In the RO desalination process, seawater is fed to a semi-permeable membrane which allows pure water to pass through it under a pressure (800 psi) while excluding the passage of dissolved solids (salts). The key to long membrane life is to remove suspended solids present in most feed seawater supplies prior to the RO membrane. Navy RO systems use single-use/disposable cartridge filters prior to the RO membrane. At the membrane surface, where selective mass transfer occurs, suspended solids coagulate and foul the RO membrane resulting in a resistance to water passage, reduction in performance, and eventual membrane failure. Seawater in littoral zones and coastal areas contain higher magnitudes of suspended solids than in the open ocean, and these solids must be removed for efficient operations in these areas.

Advanced water treatment technologies are needed to overcome these deficiencies to produce fresh-water in littoral and coastal waters. Since Navy RO plant installations began in the early 1990s, technology to remove suspended solids has matured significantly. In 2003, the Office of Naval Research (ONR) initiated the Expeditionary Unit Water Purification (EUWP) program to develop advance water treatment and desalination technologies to focus on reducing the cost of desalination for military and civilian needs ashore. The program had two components:

(1) an S&T component which sought to invent, evaluate, and develop new technology through contracts with experts in the public sector; and,

(2) the demonstration of advanced technologies in two demonstration plants–one of which was a 300,000 gallon/day demonstration plant to validate for aircraft carrier application.

Among the advanced technologies developed and evaluated under this program were flushable, reusable microfilters and electro-coagulation systems for RO prefiltration; chlorine and fouling resistant and high flux RO membranes; high efficiency pumps and energy recovery devices; and advance water polishing systems. The Machinery and Engineering Department of NSWC Carderock Division, located in Philadelphia, Pa., is leading the development of these systems for ONR as well as the development of the prototype 300,000 gallons/day demonstration plant presently under test.

Leveraging the technical successes of the EUWP, continued development has been proposed to meet emerging naval requirements under the ONR Future Naval Capabilities (FNC) program. This development includes promising water treatment and desalination technologies, as well as a shipboard desalination plant fully capable of reliable operation in the littoral and coastal zones. This FNC program–the Advanced Shipboard Desalination Program–would incorporate advanced technologies into Navy RO plants to enable them to process heavily particle-laden seawater effectively and efficiently. In addition, the new technology will reduce RO energy consumption by 65 percent, reduce system size and weight by 40 percent, reduce acquisition cost by 20 percent, and reduce the cost per gallon of water by 75 percent.

The EUWP Generation 2 Demonstration System is being set up for its six-month demonstration test at the Naval Facilities Engineering Service Center, Port Hueneme, Calif. The demonstration unit, which is composed of these two skids, produces 300,000 gallons/day. This unit would replace the two distillers currently used in a machinery room aboard an aircraft carrier, which produce only 200,000 gallons/day.
Photo by David Nordham, NSWC Carderock Division.

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Machinery Systems

Strengthening and Expanding the Backbone

Navy Improves Its Own Data Multiplexing System and Aids South Korea in Developing a Similar System

By Leslie Spaulding

Long before networks were common, the Navy developed a backbone to enable various shipboard systems to interface. This backbone continues to evolve with technological advances and ensures the readiness of mission-critical systems. In keeping with the nation's new Cooperative Strategy for 21st Century Seapower, the Navy is aiding its allies in meeting their needs in networking their shipboard systems.

The Navy began exploring this technology in the 1970s. The AN/USQ-82(V) Data Multiplexing System (DMS) was the first network installed as part of a new ship class design, the DDG 51 Class. Under a Naval Sea Systems Command program, it was designed by what is now Boeing Integrated Defense Systems in Anaheim, Calif., primarily to reduce the amount of point-to-point cabling on a ship, supporting many legacy systems with unique interfaces. The DMS allows disparate user systems to talk to one another. These systems included machinery control, steering control, damage control, some indicating and alarm systems, some combat systems, and navigation systems. At the time, this was real state-of-the-art technology. It is still considered the mission critical ship-wide network for DDG 51 through DDG 78.

Naval Surface Warfare Center, Carderock Division's involvement with the DMS began in the 1980s. Initially, the involvement was small–testing the DMS on the DDG 51 Land Based Engineering Site (LBES) in Philadelphia, Pa. A key player in installing, supporting, and testing the DMS network at that site, Division engineer Tom Morris evolved into one of the Navy's premier technical experts for this system. With the evolution of the technology and Morris' expertise in troubleshooting issues in the fleet, Carderock Division took on the role of in-service engineering agent in 1996.

By the early 1990s, fiber optics was being introduced shipboard, and the DMS was upgraded. This made the system cheaper because it required less equipment in the network backbone, and it was more capable, increasing the bandwidth four fold. Boeing designed the Fiber Optic (FO) DMS and introduced it on the DDG 79. Carderock has successfully supported the FODMS on every install from DDG 79 through DDG 102, which was recently commissioned. "The key with going to fiber optics is that we were able to introduce a less expensive, more capable, more robust network. One of the major capability and survivability enhancements introduced with FODMS was Active Redundancy," said Carderock Division's DMS Program Manager Steve Walicki. "When a user connects to FODMS, all the data is sent simultaneously over two active redundant backbones and on to the other user. The network decides what backbone to process the data from and then drops the same message from the other backbone. If the ship takes damage to one network backbone, and it has to reconfigure, the network is still sending the data

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STRENGTHENING AND EXPANDING (Continued from page 9)

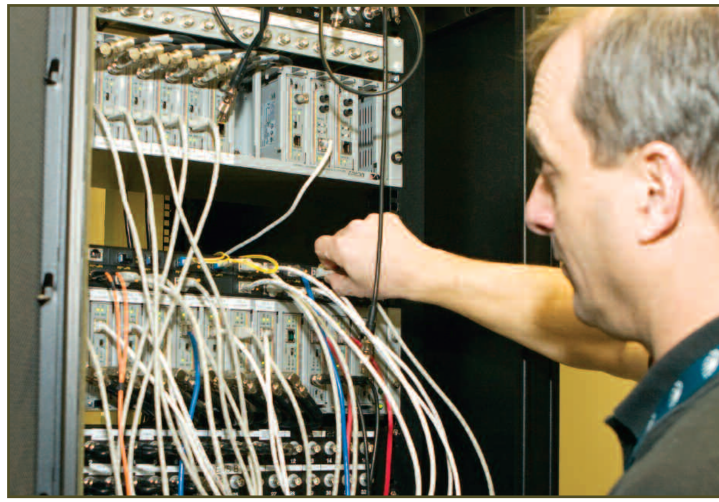
on the other backbone. So we have literally zero reconfiguration time for the network. This is critical to the ship."

He added, "Currently, we're working on the next upgrade of this network to the Gigabit Ethernet DMS (GEDMS) as part of the DDG modernization program." This technology will be installed in FY 10 during construction on DDG 111 and 112, the last two ships of the class. Then as part of the DDG Modernization backfit effort, GEDMS will eventually replace all of the existing DMS and potentially all of the FODMS networks. This work, which will begin in FY 10, involves up to 60 ships.

FODMS is also about to find its way aboard three South Korean ship sets as part of the Aegis Program. For some time, the U.S. Navy has supported allied navies by sharing its combat system under the Foreign Military Sales Program. These nations include Spain and Japan. The newer Japanese destroyers incorporate the FODMS as part of the design for navigation distribution. Carderock Division provided aid in configuring and installing some of the equipment, but Boeing, as the design agent, had the main on-site support role for that program.

As a result of that effort, South Korea expressed interest in incorporating a similar FODMS network. This system was produced by DRS Electronic Warfare and Network Systems out of Buffalo, N.Y. DRS entered into a work for private parties agreement with Carderock Division to support installation and testing of the network and integration of the navigation users. Under this agreement, Division engineers are supporting three South Korean destroyers. The first ship is currently in construction. DRS is working with Carderock Division to test its designs on the DDG 51 LBES before installing aboard ship. An engineer from Carderock Division supported installation of the system aboard the first ship in the fall 2007. Additionally, two Division engineers traveled to South Korea to provide detailed training on the FODMS equipment, operation, maintenance, and troubleshooting. Attending that training were South Korean Navy personnel and shipyard workers. In spring 2008, Carderock will complete its support of the first destroyer, and similar support will begin on the second ship.

Whether carrying data for a U.S. Navy ship or an allied ship, the AN/USQ-82 is a mission-critical network backbone, supporting a wide variety of users whose systems ride on the network. These include many NSWCCD systems as well as systems from other commands such as SPAWAR, NSWC Crane Division, NSWC Dahlgren Division, NSWC Port Hueneme Division, and NAVSEA.



Above: NSWCCD engineer Thom Morris checks the user connections on the FODMS installed at the test site in Philadelphia.
Photo by Larry Hawkes, NSWC Carderock Division.

"Although the AN/USQ-82 (V) program office resides at NSWC Dahlgren, a large part of the success of this program is due to the cooperation and close working relationship of other Navy field activities," said Richard Kahn, DMS/FODMS/GEDMS Program Manager. "The most crucial participating Navy field activity is NSWCCD Philadelphia, the in-service engineering agent. The seamless working relationship between the two NSWC organizations sets an example for future Navy programs."

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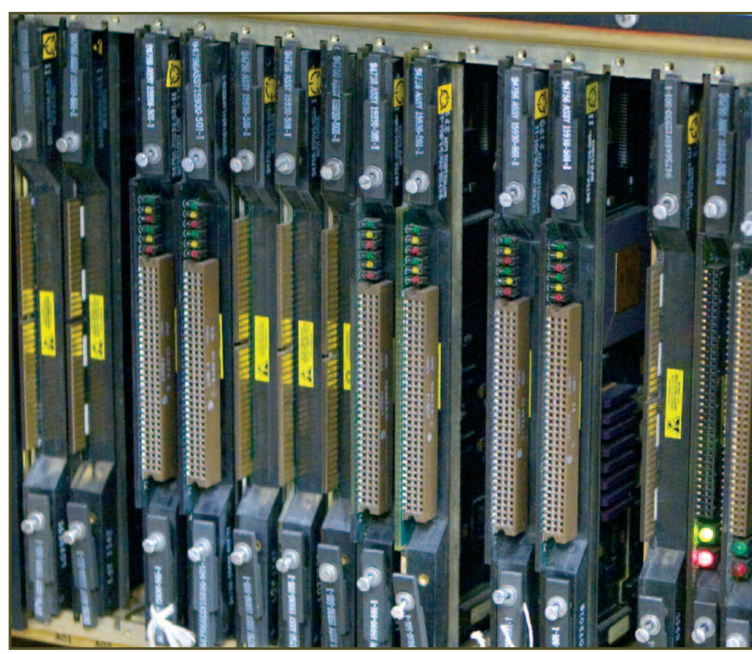


Right: The Input/Output Unit with system and user modules in place.
Photo by Larry Hawkes, NSWC Carderock Division.

COMPOSITE PRIMARY HULL

Increasing Payload and Range of Navy Ships with Lightweight, Affordable Composite Hulls

By William Palmer

Composite researchers at the Naval Surface Warfare Center, Carderock Division (NSWCCD) are collaborating with international navies, fabricators, shipbuilders, and academia to assess the feasibility and risk mitigation qualities of affordable composite materials and structures when used in Navy ship designs. Additionally, they are evaluating the structural and shock performance of composite hull and hybrid steel-to-composite hull structures for small and medium-sized surface combatants. Much of the investigation is being sponsored by the Office of Naval Research (ONR).

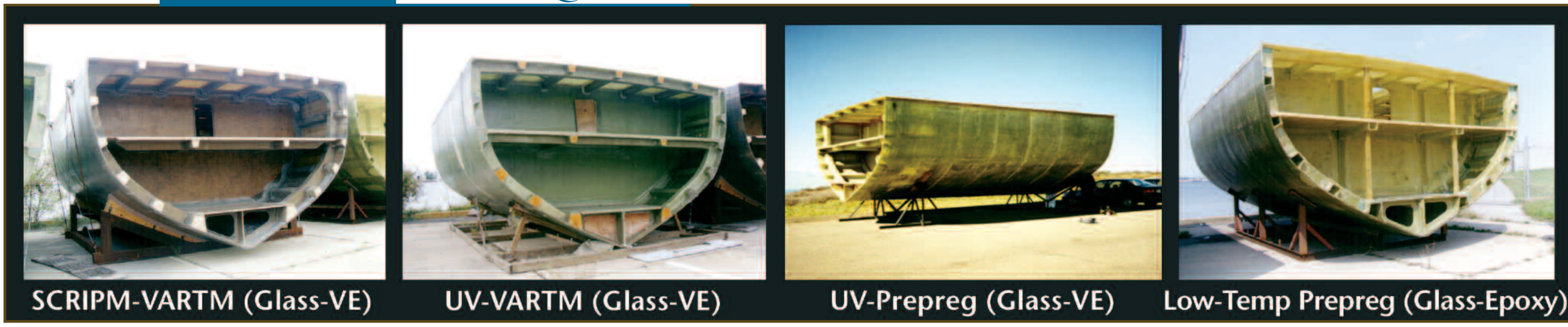
As far back as the Vietnam War era, composites have been used in Navy ships. Such usage began with fiberglass-constructed deckhouses on river patrol craft. Navy vessels of today like the Mine Hunter Coastal (MHC) Class use composites in their primary hull structures. These structures include the main deck, the hull itself, and longitudinal and transverse bulkheads. In fact, MHC Class vessels are constructed entirely of glass-reinforced plastic (GRP) composites.

Cost is one area in which the use of composites is having a big effect. “If you look at cost per pound,” says Dr. Loc Nguyen, a structural engineer and program manager with NSWCCD, “steel is much cheaper. However, a vessel made of composites is much lighter in weight, and when fully optimized it is possible to achieve as much as a 30 percent to 50 percent structural weight reduction.” Nguyen says weight savings of about 30 percent would be associated with the use of GRP, considered to be a baseline marine-grade composite material. However, approximately 50 percent weight savings could be realized with the use of higher performance composites utilizing carbon fiber or hybridized reinforcements of carbon, glass, and polymer fibers.

The reduction in shipboard structural weight, allows greater payload, cruising range, speed, or combinations of several performance improvements. Life-cycle cost reductions can also be realized through the combination of cost savings with greater cruising range and the general improvement in durability and reduced maintenance requirements. In addition, the use of composite materials and fabrication methods allows an improved integration of signature control attributes in the structural design which, in turn, contributes to enhanced survivability.

In the development of composite primary hull applications, Carderock Division researchers have worked with several composite fabricators including Sunrez, Inc. outside of San Diego, Calif.; Seemann Composites, Inc., and Northrop Grumman Shipbuilding’s Gulf Coast Operations, both of Gulfport, Miss.; Intermarine USA; the

COMPOSITE PRIMARY HULL (Continued on page 12)



Above: Affordable, high-quality manufacturing methods used to fabricate four half-scale, composite primary hull sections of a *Corvette* ship class. Half-scale section weighs approximately 10 tons and measures about 28′ long x 20′ wide x 10′ high.
Photos/renderings on this page provided by Dr. Loc Nguyen, NSWC Carderock Division.

COMPOSITE PRIMARY HULL (Continued from page 11)

University of California at San Diego; Lehigh University in Pennsylvania; and the German and Japanese navies. In United States-German cooperative exercises, conducted from 2002 to 2005, at-sea underwater explosion tests were executed in the North Baltic sea on two half-scale composite *Corvette* hull sections. Two 22,000-pound half-scale composite hull sections were tested to determine their structural response to shock impulses.

The Navy is currently in a 5-year collaborative effort with the Japanese Ministry of Defense, under the sponsorship of the Navy International Program Office, ONR, and Carderock Division, where concepts involving composite-to-steel hybrid hulls are being researched. This effort involves design, fabrication, and static and dynamic testing of large hybrid structures.

While the optimal benefits for primary hull structure in cost and weight savings, improved durability, signature control, and other functional performance improvements are yet to be fully realized in large-scale ship production, emerging fabrication processes suggest that repeatable high quality and affordable structures for naval applications can be produced at large scale. Getting shipyards to produce composite structures needed for shipbuilding processes is challenging. Explained Nguyen, “Unless the shipbuilders can duplicate and confirm affordability and repeatability of high-quality, affordable composites in the shipyard environments, we won’t be able to convince the Navy that composite structures would be good for a primary hull.”

At universities, where academic research is helping build the foundation of composite technology, basic research is being provided. Finding application for those research conclusions, essentially scaling them up for shipyard production is often required to bridge the technologies. While academia provides the foundation, alliances with the navies of other countries are valuable in fostering common interests and resolving common challenges in the areas of composite materials and structures for naval applications. The work being done at Carderock Division in development and validation of composite structures for primary hull applications with the universities, collaborations with foreign navies, and U.S. shipbuilders is taking this technology from research to reality.

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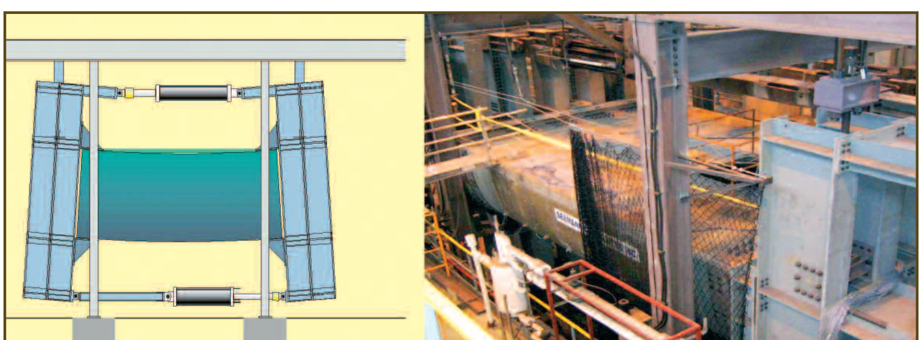


Above: Hull-girder bending tests conducted to determine the hull elastic behavior and its buckling and collapse strength.

Right: UNDEX shock tests are conducted to investigate the hull integrity and its structural response under dynamic shock loads.

Environmental Quality Systems

Navy Environmental Success Story

The Plasma Arc Waste Destruction System to Reduce Waste Aboard CVN 78

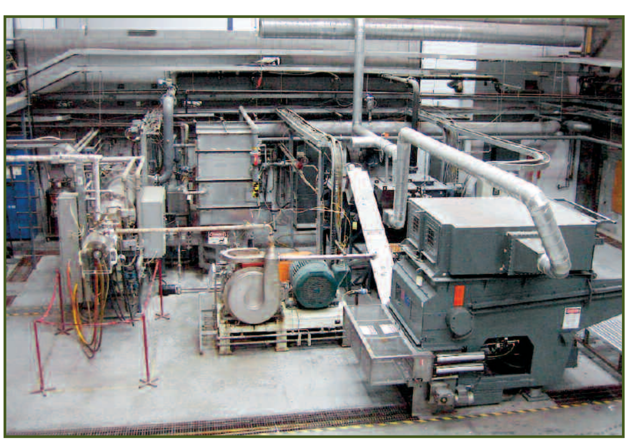
By Gary Alexander

The Plasma Arc Waste Destruction System (PAWDS), an advanced waste thermal treatment system for ships, is a concept-to-reality success story. The PAWDS uses plasma energy, at temperatures over 5,000^{o}C, to efficiently destroy combustible shipboard waste. NSWC Carderock Division has collaborated with PyroGenesis Canada, Inc. (PGC) in Montreal, Canada, since 1999 to develop the PAWDS for installation aboard *USS Gerald R. Ford* (CVN 78), the Navy's next generation aircraft carrier. This system will process 6,800 pounds per day of shipboard, non-food, combustible, solid waste while at sea.

The PAWDS program started at NSWC Carderock Division in the early 1990s as a 6.2 Exploratory Development effort funded by the Office of Naval Research (ONR) to determine if plasma technology was a feasible method to combine and treat multiple waste streams. The combined waste stream included plastics, which required storage after processing by the legacy solid waste equipment. In 1999, the technology transitioned to a three-year 6.3 Advanced Technology Demonstration (ATD) Program, which culminated in a successful demonstration test of a full-scale prototype in December 2001. At the completion of the ATD Program, it was clear the technology could be employed for processing combustible solid waste, but additional system and component improvements were necessary to address U.S. Navy specific needs and concerns.

In 2002, the CVN 21 (now CVN 78) Program Office requested that Carderock Division perform a technical assessment and cost analysis to evaluate the feasibility of integrating PAWDS aboard CVN 78 in place of the typical suite of solid waste equipment. This assessment concluded that a PAWDS and appropriate backup legacy equipment would fit aboard CVN 78 and meet the ship's performance requirements. The PAWDS was selected for use aboard CVN 78, and Carderock Division was tasked with developing a shipboard system. Meanwhile, PGC licensed the Navy-patented plasma fired eductor (PFE) from NSWCCD for future commercialization and began making improvements to the ATD system. In 2003, PGC designed and installed a production PAWDS system aboard Carnival Cruise Lines' *M/S Fantasy*. The cruise ship's system is still in operation today

NAVY ENVIRONMENTAL (Continued on page 14)



Left: The Plasma Arc Waste Destruction System (PAWDS) Engineering Development Model in the contractor's facility in Montreal, Canada.
Photo provided by Gary Alexander, NSWC Carderock Division.

NAVY ENVIRONMENTAL (Continued from page 13)

Above: Sailors troubleshoot the PAWDS system via a message display.
Photos on this page provided by Gary Alexander, NSWC Carderock Division.

Right: A Navy Sailor performs maintenance on PAWDS mill.

Below: A Navy Sailor loads the PAWDS shredder with waste.

and has logged nearly 5,900 hours while processing an estimated 2.4 million pounds of solid waste. PyroGenesis received MARPOL type certification for PAWDS in 2006 for processing both solid waste and waste oil.

Under contract with the U.S. Navy, PyroGenesis made several additional critical design improvements that resulted in a process rate in excess of 400 lb/hr and less downtime for cleaning due to reduced ash accumulation in the thermal unit. In 2004, a duplicate PAWDS Engineering Development Model (EDM) was constructed for the Navy. The PAWDS was officially approved for installation aboard CVN 78 in April 2005 after the program accomplished a major milestone by successfully completing a long duration (7-day) land-based test of the EDM in December 2004.

The PAWDS-EDM operates in a three-step process, consisting of (1) a waste pretreatment system that downsizes waste particles to lint-like material, which is easily-gasified, (2) a combustion system that first gasifies and then combusts the waste, and (3) an exhaust gas treatment system that removes pollutants. The process is highly automated and requires minimal skills to operate. It can be started and shut down with the push of a button. The programmable logic controller advises the operator and provides the maintainer with assistance in troubleshooting the system via a message display.

Following several additional equipment safety and design enhancements between 2005 and 2007, Carderock Division achieved another major milestone of successfully completing a 60-day endurance test of the PAWDS-EDM from June 17 through August 19, 2007. The PAWDS Team overcame technical and spare part support hurdles, schedule delays, and budget constraints to complete the test. Navy Sailors from *USS Carl Vinson* (CVN 70) operated and maintained the EDM around-the-clock over a period of 64 calendar days to simulate a partial ship deployment.

This test evaluated the PAWDS' readiness for installation aboard CVN 78. The PAWDS team members provided continuous oversight of the time-critical preparation and test execution phases. During the test period, the EDM met all performance and emission requirements by processing 204 tons of surrogate Navy waste at an average rate of 439 lb/hr and average carbon monoxide (CO) output of 124 mg/MJ. An evaluation of the operational availability is underway.

The CVN 78 is in the preliminary design stage for the shipboard production system, led by the lead design yard (LDY), Northrop Grumman Shipbuilding. The LDY will purchase the production system in accordance with the Navy-developed performance specification. The CVN 78 Program Office has tasked NSWCCD with leading the PAWDS development and assisting in its integration aboard CVN 78. PAWDS development supports the Carderock Division and NAVSEA mission to provide ships with cost-effective technologies and processes to enable them to comply with environmental regulations. Compared to the legacy equipment, it is estimated that PAWDS will save CVN 78 $38 million over the life of the ship due to the reduced workload to operate and maintain the system.

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VULNERABILITY & SURVIVABILITY SYSTEMS

AIR GUN TECHNOLOGY

Reducing Full-Ship Shock Trial Costs Using Oil Industry Technology

By William Palmer

Responding to a need for revising the way we conduct full-scale shock trials, Carderock Division researchers are exploring the use of compressed air instead of explosive charges to impart a high-energy impulsive loading to a ship hull. Leveraging off the research of the United Kingdom's Ministry of Defense, begun in 1999, the use of air gun technology has several promising aspects.

Congressional legislation mandates live-fire testing and evaluation on newly-delivered combatant vessels. A full-scale shock trial partially satisfies that mandate. The Navy is required to secure permits to conduct shock trials at sea. To secure these permits, an environmental impact statement typically needs to be filed, a process which can take three to four years to complete and costs the Navy on the order of $3 million per filing.

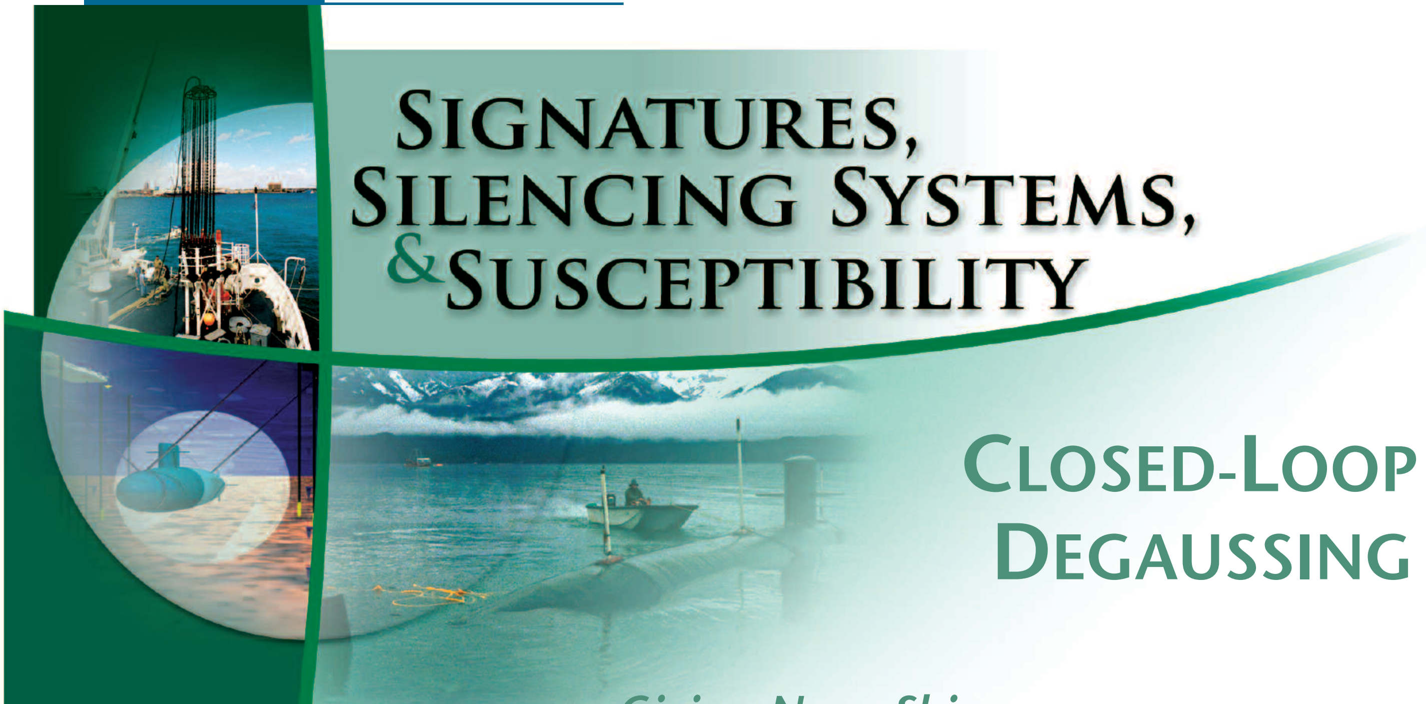
On the other hand, a full-scale shock trial is a truly valuable test. During these trials, crews are "fighting the ship," or placing the ship in simulated combat, with various integrated ship systems fully energized and operating. Shocking a ship while operating in this way gives the Navy precious insight into how these interconnected systems perform under the duress of combat, without actually being in a combat situation.

Four years ago, a Full-Scale Shock Trial Alternative Integrated Product Team (FSST IPT) was established to determine and execute a suitable replacement strategy for these shock trials. Several elements that contribute to this overall strategy were explored, such as advanced modeling and simulation; surrogate testing in which a decommissioned ship of similar construction and geometry to an active vessel is used for testing; and focused component testing.

Concurrently with the IPT investigation, the Navy's Small Business Innovation Research (SBIR) program put out a solicitation to identify an alternate energy source to produce high energy impulsive loading similar to an explosive device. The solicitation resulted in 13 proposals. The Phase One SBIR program executed three of the proposals. A Phase II program was executed for two of the Phase I offerors, and finally the current Phase III SBIR program has chosen the air gun technology for further development for shock trial usage. Air guns are basically commercial-off-the-shelf technology supplied by a Houston, Texas, based firm that provides air guns to the offshore oil industry to pulse the ocean floor with repeated bursts of impulsive energy to locate oil deposits.

The air gun technology has critical features that are superior to explosive charges. The impulse from air guns is focused on a very small spatial volume, so that air gun arrays can be deployed close to a ship hull with the energy radiated primarily at the ship and a small volume of the local ocean environment. In contrast, large explosive charges are placed hundreds of feet from a ship, radiating shock wave energy into a significant area of the ocean environment in a spherical pattern, i.e., in all directions at once. Thus air gun usage enables a greatly reduced shock energy footprint to the environment. Both methods can achieve a similar impulse level required by

AIR GUN TECHNOLOGY (Continued on page 17)



Signatures, Silencing Systems, & Susceptibility

Closed-Loop Degaussing

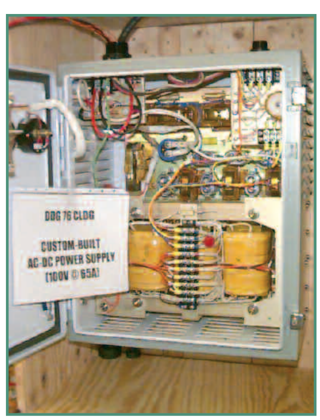
Giving Navy Ships Advantage in Stealth

By William Palmer

Researchers at the Naval Surface Warfare Center, Carderock Division (NSWCCD) demonstrated the effectiveness of Closed-Loop Degaussing (CLDG) system in magnetic signature reduction and maintenance for steel-hulled surface combatants and wood-hulled minehunter vessels. This technology is currently in use in the fleet in the *Avenger* (MCM-1) Class minehunter vessels. Implementation guidelines for CLDG in steel-hull ships were developed and are available to guide the surface ship community going forward.

CLDG was developed to detect and compensate for at-sea changes in a ship's permanent magnetic signature ("PERM"). In demonstrations, CLDG proved useful in maintaining an optimized magnetic signature in the forward area. It also reduces the need for degaussing system re-calibration, saving operational time and cost.

A degaussing system is an onboard set of current-carrying coils and associated power supplies. Electrical currents running through the coils generate magnetic fields, which are used to cancel the ship's magnetic signature at mine depth. Calibration of Navy degaussing systems occurs at dedicated U.S. Navy magnetic silencing facilities. In recent years, ships equipped with the advanced degaussing system (ADS) have begun arriving in the fleet. ADS features more degaussing coils than legacy degaussing systems, with individual computer-controlled power supplies dedicated to each coil. This results in greater flexibility, leading to improved residual signatures relative to legacy systems. The modern computer-controlled nature of ADS also enables the implementation of CLDG.



Above: Degaussing coil power supply.
Photo courtesy of William Gay, NSWC Carderock Division.

The CLDG system works with ADS, providing piggyback protection where ADS is blind–the detection and compensation of PERM change. PERM is the largest component of ship magnetic signature and changes significantly over time due to stress caused by voyage effects while the ship is in the presence of ambient magnetic fields different than those of the calibration site.

The CLDG system features an onboard suite of magnetometers intended to detect PERM change. During CLDG system calibration, various orthogonal PERM change states are imparted to the ship, and simultaneous onboard and mine-depth measurements are acquired.

Once the ship is at sea, CLDG continuously monitors the onboard sensors. The CLDG algorithm, which can best be described as a simple transfer function, is a mathematical representation of the relationship between a system's input and output, or in this case between the onboard and mine-depth sensor measurements obtained during calibration. Electrical engineer Will Gay,

CLOSED-LOOP DEGAUSSING (Continued on page 18)

Right: Open-ocean shock testing of the *USS Mobile Bay* (CG 53) using large amounts of explosives. Investigation of compressed air usage could mitigate the disadvantages of explosives in such shock testing scenarios.
Photos and rendering this page courtesy of Fred Costanzo, NSWC Carderock Division.

AIR GUN TECHNOLOGY (Continued from page 15)

Navy shock testing standards. The primary difference is that an explosion can achieve that level almost instantaneously, whereas the compressed air has a longer “rise time” to arrive at the same level.

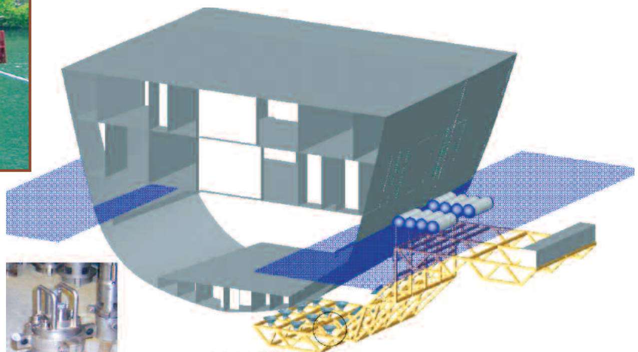
Another positive feature of air guns is that they are portable and by design have the flexibility to be configured in arrays that can wrap around the contour of a ship’s hull. Pressurized remotely by air compressors to about 3,000 psi, the air gun arrays are transported to the ship in port.

Seeking to maintain its high degree of superiority as a preeminent maritime power, while remaining committed to global security and prosperity, the Navy, with assistance from Carderock Division researchers, is looking to air gun technology to provide a viable full-ship shock trial testing regime, while greatly reducing trial costs and affecting a greatly reduced impact to the environment.

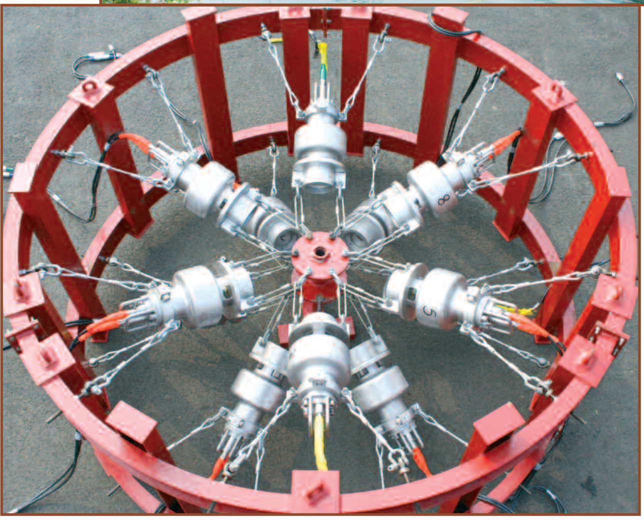
Above: A plume generated by an air gun array during testing.

Right: An inset image showing the twin air gun assemblies in more detail.

Below A framework with two air gun assemblies being lifted into place for testing.



Above: A computer rendering showing placement of an air gun array against a ship's hull. Inset shows detail of an individual air gun assembly.



Left: A circular array of air guns. Unlike explosives, air gun arrays are placed close to a ship to impart shock energy.

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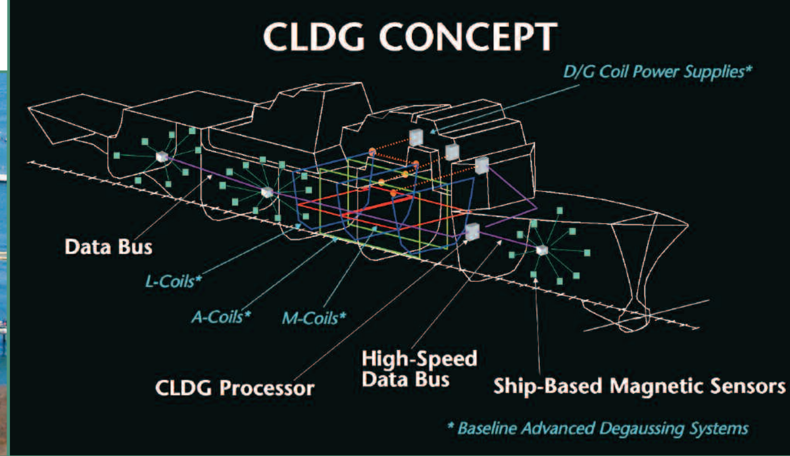
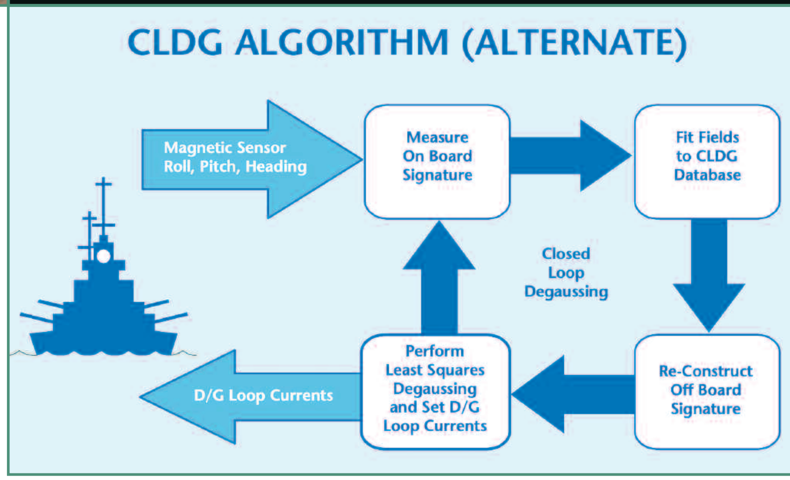
Above: *USS Higgins* in San Diego deperming slip. Note the perming coils wrapped around the exterior of the ship.





Top: Schematic of CLDG sensor locations onboard.
Bottom: Conceptual diagram of CLDG operation.

Photo and graphics on this page courtesy of William Gay, NSWC Carderock Division.

CLOSED-LOOP DEGAUSSING (Continued from page 16)

involved with the CLDG investigation, explains that the closed loop provided by equipping the ship with magnetometers is created specifically to serve the function of Delta PERM signature prediction. “During calibration,” he says, “we develop the transfer function between what the onboard sensors read and what the offboard sensors read. Once the ship leaves the calibration facility, the CLDG system monitors the onboard sensors and plays the onboard signature through the transfer function. In this way, the CLDG algorithm computes the mine-depth PERM change at any point in time, anywhere the ship goes.” CLDG then adjusts the degaussing system to compensate for detected PERM change.

The CLDG program started in 1990, and was set up as a new technology development agreement with a foreign-country partner. U.S. researcher teams and their counterparts in the French Navy developed CLDG for non-ferrous hulled ships. The French team used its *Cybele* Class minesweeper vessel as a testbed, while the U.S. teams used an *Avenger* Class minesweeper. The French team based their modeling on numerical computation, in which they used finite element models in mathematical approaches. This approach was chosen owing to the lack of measurement facilities available to the French Navy. In contrast, the U.S. team employed an empirical approach, using sensor measurements and physical scale models to form their algorithm. There was some cross-referencing as both teams developed their algorithms, in which they applied their own algorithms to the opposite CLDG ship.

The initial steel-hull testing was performed on a former East German missile corvette, the *Hiddensee*, which had been procured by the U.S. Navy as a research vessel. This was the genesis of the current steel-hull CLDG design. A recent Advanced Technology Demonstrator for the DDG 1000 program used a prototype CLDG system installed on an *Arleigh Burke* (DDG 51) Class destroyer to detect and compensate large PERM changes in the forward area.

Information from CLDG sensors is also considered as valuable input for tactical decision aids (TDA), which are onboard planning tools used by warships to help provide real-time susceptibility information. With a CLDG system onboard, a ship is more self-aware of its magnetic susceptibility and as a result is better able to plan its activities in areas of heightened risk.

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TECHNOLOGY & INNOVATION

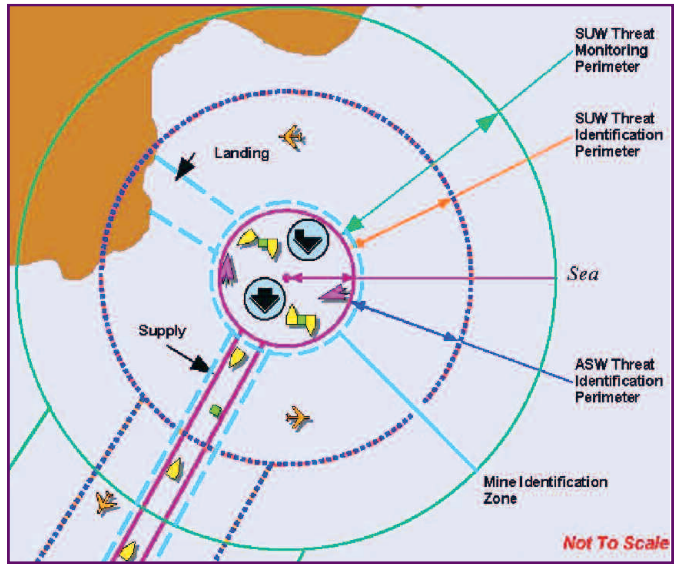
UNMANNED VEHICLE SENTRY SYSTEM

Keeping Sea Base Assets Safe with Autonomous Sentry Vehicles

By Daniel Dozier

The future state of military operations includes unmanned systems possessing a high degree of autonomy and decision-making ability and efficient man-machine interfaces to transform the combatant commander's intent into system decisions and ultimately machine actions. This future vision is acknowledged in the Office of the Secretary of Defense Unmanned Systems Roadmap (2007-2032), published in December 2007. (Access http://www.acq.osd.mil/usd/Unmanned%20Systems%20Roadmap.2007-2032.pdf to see this document.) This OSD document summarizes the growing evolution in technology that is enabling a new capability to project military power through the cost effective use of unmanned systems while reducing risk to human life. DoD is spending $4 billion per year over the future years defense plan on unmanned systems. While tremendous advances have been made, the document also points out where significant advancements are still required to have the unmanned system remove the human from the "dull, dirty, and dangerous" missions.

Technological advances in the physical and material sciences, manufacturing capabilities, control theory, computing power, and other technology have enabled scientists, engineers, and inventors to develop new unmanned machines to meet warfighter needs. Yet there remain many technological challenges facing the transformation of these individual unmanned vehicles into autonomous unmanned systems. The critical piece that appears to be lagging and in need of technological advancement is an overall autonomous system capability to manage the individual elements into a system of unmanned systems that can perform a mission, rather than the individual elements performing tasks.



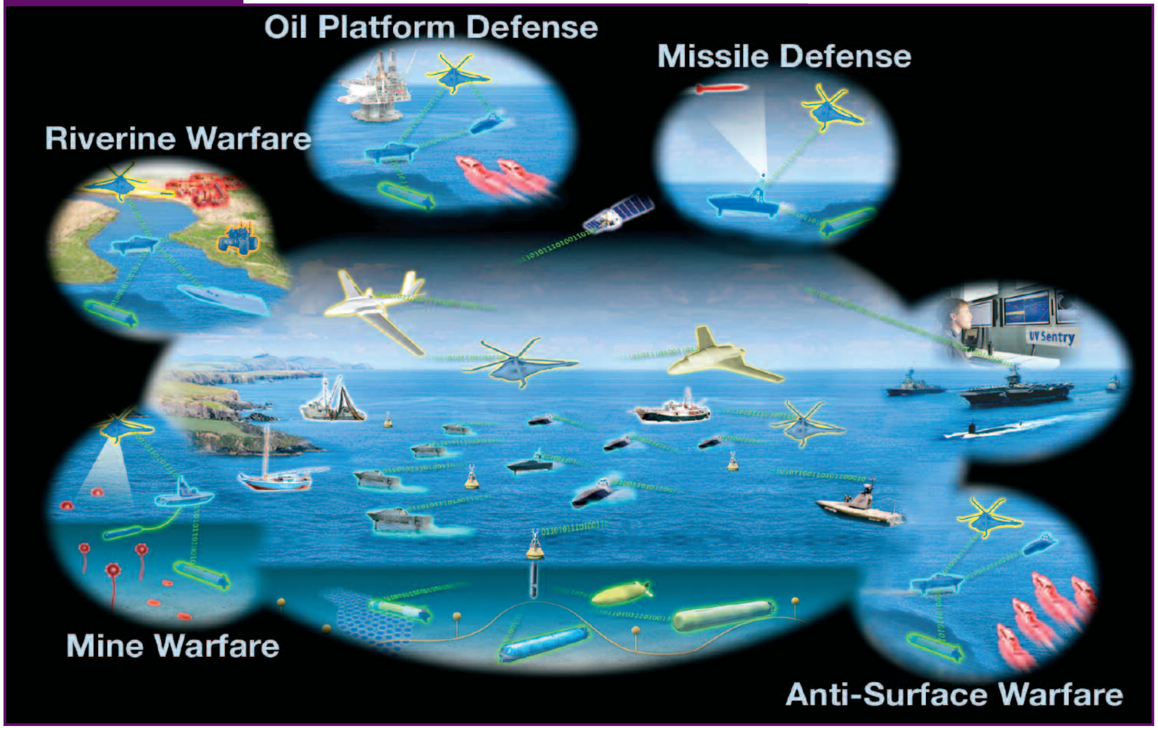
Scenario Definition for Innovation Center Study (circa 2005).
Rendering provided by Daniel Dozier, NSWC Carderock Division.

A cross-Navy Laboratory effort that began in the Carderock Division Innovation Center in July 2005 has continued with the persistent advocacy of Dr. Joe Corrado (retired February 2008) of Carderock Division and Jim Simmons of SPAWAR Systems Center San Diego and several others in the Navy S&T and R&D community. The initial Unmanned Vehicle Sentry (UV Sentry) Team was formed for a six-month collaborative effort from members of Carderock Division and other Warfare Centers, and the SPAWAR Systems Center San Diego to employ a systems engineering approach with an overall theater level warfare systems perspective to:

> *"Develop a concept of operations for a system of unmanned systems that will serve within Sea Shield as sentries to sense and identify current and projected surface and subsurface threats to Sea Base assets; and design the corresponding FORCEnet Services Infrastructure-based architecture and suite of unmanned vehicles."*

Using the Scenario Definition in the figure above, the original Innovation Center Team conducted their study by considering mission areas appropriate for an Unmanned Vehicle Sentry System of systems,

UNMANNED VEHICLE (Continued on page 20)



UV Sentry Operational View.
Rendering provided by Daniel Dozier, NSWC Carderock Division.

UNMANNED VEHICLE (Continued from page 19)

including anti-surface warfare, mine warfare, anti-submarine warfare, signals intelligence and electronic warfare, chemical/biological/radiological threat detection, and unmanned system replenishment. They concluded their study with a concept of operations for the UV Sentry system, an inventory of vehicle characteristics needed, and the technology drivers needed to address shortfalls from today's state of the art.

Since the completion of that Innovation Center effort two years ago, a consortium of Navy Laboratory leaders who believe in the concept has been growing. In the ensuing briefings and discussions with potential customers and stakeholders, the UV Sentry Team has found that the Navy is very well organized and prepared to move forward around the individual elements that make up the UV Sentry concept, but no one organization is responsible for the whole system architecture. Additionally, many of the needed technologies for this system architecture lack current investment. That is where a systems engineering approach performed through the combined knowledge and skills of the Navy Laboratories can fill the gap.

The current UV Sentry Team envisions:

An autonomous unmanned force capability that spans large geographical space and media to provide long-term, persistent and accurate surveillance, detection, and engagement of threats for multiple missions.

Looking to further develop the concept beyond the initial Innovation Center study, the Office of Naval Research funded a Technology Workshop in May 2007 with wide participation by subject matter experts from the Naval Undersea and Surface Warfare Centers, SPAWAR Systems Center San Diego, Naval Air Systems Command, Naval Post Graduate School, DARPA, ONR, and others. In late 2007, SPAWAR Systems Center San Diego conducted a six-month Innovation Center study on autonomous command and control architecture for an unmanned system of systems, detailing the technology gaps from the command and control perspective. Naval Post Graduate School is leading an effort to define the system architecture of the UV Sentry system, as portrayed in the operational view in the figure above. In 2008, ONR is funding a warfare analysis of the UV Sentry system concept by the Center for Naval Analyses (CNA) to be supported by the government-led consortium of the UV Sentry Team.

The team is continuing to brief potential customers and stakeholders and is very optimistic that in the not-too-distant future, after system developments, demonstrations, and field experiments, combatant commanders will have the ability to direct an UV Sentry system of systems to protect a sea-based asset, removing the Warfighter from the dull, dirty, and dangerous.

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Ship Integration & Design

This core equity applies specialized expertise for surface and undersea vehicle design including early concept development, assessment and selection of emerging technologies, integration of selected technologies into optimized total vehicle designs, and evaluation of those technologies and designs for cost, producibility, supportability, and military effectiveness.

Machinery Systems

This core equity provides full-spectrum technical capabilities (facilities and expertise) for research, development, design, shipboard and land-based test and evaluation, acquisition support, in-service engineering, fleet engineering, integrated logistic support and concepts, and overall life-cycle engineering.

Hull Forms & Propulsors

This core equity provides the Navy with full-spectrum hydrodynamic capabilities (facilities and expertise) for research, development, design, analysis, testing, evaluation, acquisition support, and in-service engineering in the area of hull forms and propulsors for the U.S. Navy.

Vulnerability & Survivability Systems

This core equity provides full-spectrum capabilities (facilities and expertise) for research, development, design, testing, acquisition support, and in-service engineering to reduce vulnerability and improve survivability of naval platforms and personnel.

Environmental Quality Systems

This core equity provides facilities and expertise for research, development, design, human systems integration, acquisition support, in-service engineering, fleet support, integrated logistic concepts, and life-cycle management resulting in mission compatible, efficient and cost-effective environmental materials, processes, and systems for fleet and shore activities.

Signatures, Silencing Systems, & Susceptibility

This core equity specializes in research, development, design, testing, acquisition support, fleet guidance and training, and in-service engineering for signatures on ships and ship systems for all current and future Navy ships and seaborne vehicles and their component systems and assigned personnel.

Structures & Materials

This core equity provides the Navy with specialized facilities and expertise for the full spectrum of research, development, design, testing, acquisition support, and in-service engineering in the area of materials and structures.


NAVSEA
WARFARE CENTERS
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